Spectra of Cluster Galaxies at $z \sim 0.4$

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Abstract. The "MORPHS" group has obtained an extensive spectroscopic dataset of galaxies in the fields of 10 rich clusters at $0.37 < z < 0.56$; the stellar population properties of about 700 objects have been determined from a detailed analysis of spectral line strenghts and colours, up to a galactic absolute magnitude $M_V = -20.3$ mag. Morphological informations for a consistent fraction of our sample have been previously derived from deep images of the central regions of these clusters taken with the WFPC-2 on board the HST. Spectral and morphological features can be compared in order to study the star formation histories of the different galactic types in clusters; here we show some preliminary results of this comparison.

1. Introduction

Galaxies in rich clusters at low redshifts have stellar and structural properties significantly different from objects in the nearby field. Although it is well established that galaxy evolution *depends* on the environment, it is still not clear which/how/when/how-much environmental effects determine or influence the main galactic properties. In clusters an unexpected strong evolution from intermediate redshifts to $z = 0$ has been detected regarding the star formation activity (from a large number of studies beginning with those of Butcher & Oemler) and, more recently, the relative fractions of the various morphological types.

The "MORPHS" group – Amy Barger, Harvey Butcher, Warrick Couch, Alan Dressler, Richard Ellis, Gus Oemler, Ray Sharples, Ian Smail and myself – has used images from the Hubble Space Telescope Wide Field and Planetary Camera 2 to study the evolution of galaxies in distant clusters. The catalog with positions, photometry and Hubble types is presented in Smail et al. (1997b), while the morphological evolution and the morphology-density relation are discussed in Dressler et al. (1997). Constraints on the formation epoch of the early type galaxy populations can be placed from their colour homogeneity (Ellis et al. 1997) and their structural parameters (Barger et al. 1997). An analysis of gravitational lensing by the clusters is given in Smail et al. (1997a).

Here we report on some first results from a large optical spectroscopic survey of 10 clusters (see Table), which should be cited as preliminary results of the MORPH's collaboration. The spectral catalog and some basic properties of the sample will be described in Dressler et al. (1998); the analysis of the dataset

and the interpretation in terms of the star formation history will be given in Poggianti et al. (1998).

2. Analysis

Redshifts and equivalent widths of the main lines have been measured for the ~ 500 new spectra, as well as for the sample of Dressler & Gunn (1992, DG92). The spectra have been classified into 6 main spectral classes according to their emission and absorption line properties and have been compared with both our spectrophotometric model (Barbaro & Poggianti 1997) and a local sample of field galaxies (Kennicutt 1992). In particular we identified the cases with a recent (post–starburst) or current (starburst) strong episode of star formation.

For a subsample of ~ 300 galaxies, the *spectral type* can be compared with the *morphological type* determined with the HST: a major goal is to investigate the star formation histories of galaxies as a function of their Hubble type and explore the connection between the strong *morphological* evolution observed (Dressler et al. 1997) and the stellar population content.

Table 1. Numbers are not definitive and include also the DG92 data. The spectra were taken with the Hale Telescope at Palomar, the William Herschel Telescope at La Palma and the New Technology Telescope at La Silla; the typical spectral range is 3500–8000/10000 Å

Cluster	z	N spectra total(cl. members)
A370	0.37	61(41)
Cl1447+23	0.37	29(21)
Cl0024+16	0.39	156(106)
Cl0939+47	0.41	164(71)
Cl0303+17	0.42	94(50)
3C295	0.46	35(25)
Cl0412−65	0.51	25(11)
Cl1601+42	0.54	106(56)
Cl0016+16	0.55	42(29)
Cl0054−27	0.56	27(13)

3. Results

The main preliminary results for cluster members are the following:

▷ As in previous spectroscopic surveys of clusters at intermediate redshifts (Couch & Sharples 1987, DG92), a large population of post-starburst objects is found: about a third of the sample show evidence of a recent starburst which ended during the last 2 Gyr.

▷ About 5% of the spectra have very strong emission lines indicative of a current starburst. They mostly belong to the lowest luminosity end of the sample. If no further star formation is assumed after this burst, according to our calculations they will fade significantly by $z = 0$.

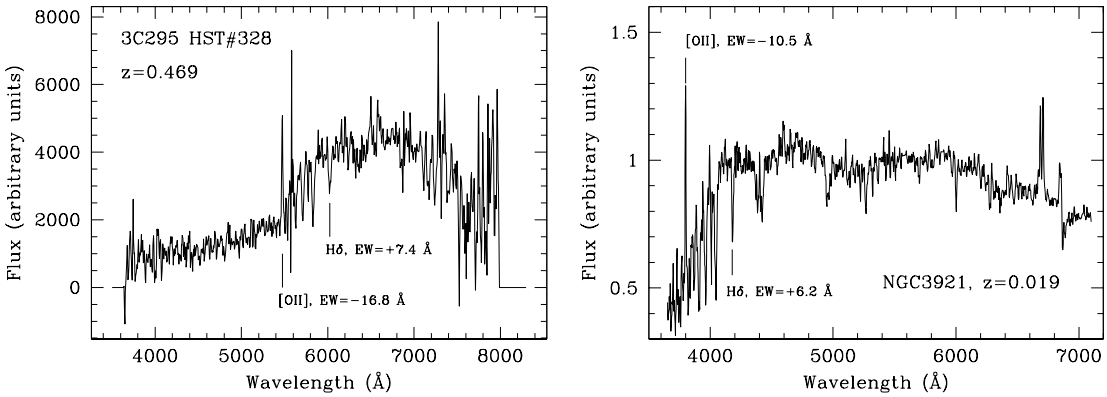

Figure 1. The spectrum of the galaxy HST#328 in 3C295 is compared with the spectrum of the merging galaxy NGC3921 (Liu & Kennicutt 1995). They both show a moderate [OII]λ3727 line and a strong Hδ line in absorption.

▷ A large number of spectra (10%) exhibit exceptionally strong higher order Balmer lines in absorption *and* the [OII]λ3727 line in emission. On the basis of our model we interpret them as objects which have had a recent intense starburst and present some current (residual) star formation activity at a much lower level. There is a number of low redshift examples of similar spectra, such as those of some merging galaxies (Fig. 1).

▷ The bulk of the early type galaxies (ellipticals and the few S0's found in these clusters) have passive spectra, with no obvious signs of current or recent star formation. However a non-negligible fraction of them have a post-starburst spectrum, with strong Balmer lines in absorption and no trace of ongoing star formation.

▷ Of the many spirals, the majority have spectra which are either "too active" or "too passive" as compared to low–redshift field spirals. The entire population of starburst galaxies and most of the post-starburst population is composed of spirals (Fig.2). Another significant fraction of the late type galaxies present a level of star formation activity which is too low for their Hubble type compared to local field spirals.

▷ Morphologically disturbed objects – asymmetric or distorted – are numerous in these clusters (Smail et al. 1997) but except for a few clear cut examples of mergers, the interpretation of the cause of the disturbance remains subjective. Most of the starburst spectra and a large fraction of the post-starburst spectra belong to galaxies which appear morphologically strongly disturbed.

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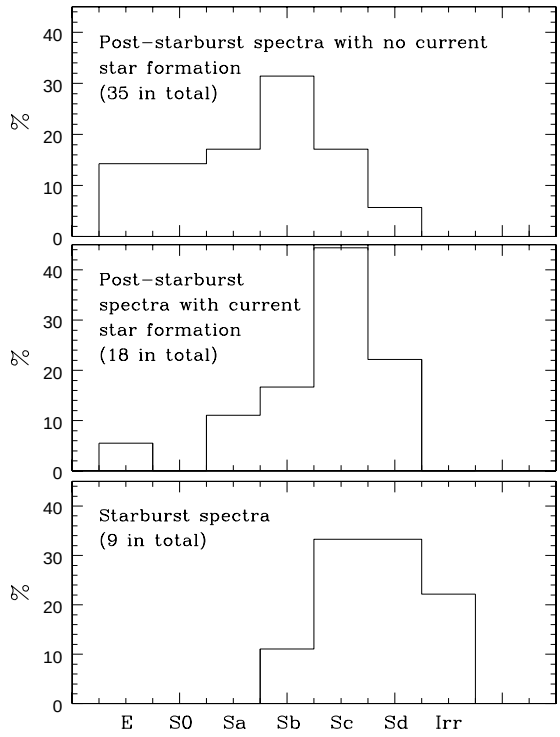

Figure 2. Morphological type distributions for objects of 3 different spectral classes.

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